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STRUCTURAL STEEL.

BY EDWARD B. DORSEY, M. AM. SOC. C. E.

READ AT THE ANNUAL CONVENTION, JUNE 10TH, 1884.

Since his former paper on Structural Steel was written (Trans. Am. Soc. C. E., February, 1884), the writer has made two trips to Europe, and has collected both there and here additional data, which are offered to this Society as a supplement to the previous paper.

The last few years have shown a rapid increase in the use of mild steel for structural purposes, especially in ship and bridge building. In shipbuilding it has passed entirely through the experimental stage. The following table of iron and steel vessels built, classed by Lloyds' Registry of British and Foreign Shipping, shows its progress within the last six years.

Years.	* Tonnage.		Per Cent.	
	Steel.	Iron.	Steel.	Iron.
1878.	4 470	517 692	.0085	.9915
1879.	16 000	470 969	.0328	.9672
1880.	35 373	459 994	.0714	.9286
1881.	42 407	696 724	.0574	.9426
1882.	125 841	851 075	.1290	.8710
1883.	166 428	933 774	.1512	.8488

The steel tonnage shows a continued increase each year, also the percentage, except in the year 1881, when the difference in price became too great to use steel profitably over iron.

The above table is taken from a recent paper read before the Iron and Steel Institute of Great Britain, by Mr. William John, of Barrow-in-Furness. He also says, in the same paper:

"We have built, at the Barrow Shipbuilding Company's Works, during the last five years, nine steel vessels, varying in size from very small ones up to vessels of 4 000 tons, and of an aggregate tonnage of 19 157 tons, with a total quantity of material amounting to 10 750 tons.

"During the same period we have built 80 000 tons of iron shipping, employing about 46 800 tons of invoiced iron. From this it will be seen that about 20 per cent. of the tonnage of 99 157 tons built at Barrow during the five years has been of steel, and out of the whole material so employed, we have not had the slightest bother with either plates or angles or beams; but it is far different with iron.

"Messrs. Denny Brothers, who were the first among shipbuilders to take up the question of steel vigorously, and who have kept the lead in it, have built during the same period nearly 68 000 tons of steel shipping out of a total of 96 000 tons, amounting to over 70 per cent. of their total.

"Mr. William Denny, as you will remember, gave his views very fully before this Institution, in a valuable paper read here in 1881, and further experience has confirmed him in those views, as I know from a communication received from him a few days ago, in which he says steel has become so uniform as to have lost interest, while iron absorbs attention from its deterioration and want of uniformity, and the men complain if they are put to work iron, on account of the amount of spoiled work involved.

* Note.—All the tons named in this paper are the long tons of 2 240 pounds.

"I believe, from what I can learn, that this experience of Messrs. Denny and ourselves in the working of steel in the shipyard, is borne out in other yards about the country."

The preceding statement by Messrs. Denny Brothers and Mr. William John are very strong indorsements of mild steel over iron, especially so, as neither of them are manufacturers of iron or steel; their evidence is entirely impartial, and this after five years' very extensive working in steel in shipbuilding; in no kind of structural work is the material so tortured as in shipbuilding; if it stands this test it should stand all others.

Messrs. Denny Brothers are among the oldest and largest shipbuilders on the Clyde; their verbal statement to me more than confirmed the preceding.

In England it is estimated that, after allowing for additional carrying capacity, owing to the greater strength of steel, and consequently comparative lightness of steel vessels over those built of iron, iron and steel vessels will stand on commercial equality when the cost of steel is two cents, and iron one and one-half cents per pound.

In bridge building steel has also passed through the experimental stage; in proof of this can be cited the success of the St. Louis bridge—the pioneer of large steel bridges,—the Brooklyn Suspension, the Niagara Cantilever, the Plattsmouth, the Bismarck and the Blair Crossing bridges, the bridge on the Northern Pacific at the second crossing of Clarke's Ford, and the number of smaller ones that have been built in Europe and India. All have given such great satisfaction that Messrs. Barlow and Baker, the distinguished engineers, have been encouraged to build entirely of steel, the New Forth bridge, with its two unprecedented spans of 1 700 feet each. The following is their specification for the steel and steel work on this bridge. This is given in full to show the practice in England, where the experience has been longer, more extensive and general than with us:

STEEL WORK.

1. Strips cut lengthwise or crosswise to have an ultimate tensile strength of not less than 30 tons and not exceeding 33 tons per square inch of section, with an elongation of at least 20 per cent. in a length of 8 inches for all steel subject to tensile stresses, and of not less than 34 tons nor exceeding 37 tons, with an elongation of at least 17 per cent. for all steel subject only to compression. The latter steel will also be tested in a suitable apparatus by direct thrust, and the depression under a stress of 34 tons per square inch, must not exceed 10 per cent. in a length of 8 inches.

2. The beam, angle, bulb, and bar steel to stand such forge tests, both hot and cold, as may be sufficient, in the opinion of the engineer, to prove soundness of material and fitness for the service.

3. Strips cut crosswise or lengthwise 1½ inches wide, heated uniformly to a low cherry red and cooled in water of 82° Fahrenheit, must stand bending double in a press to a curve of which the inner radius is one and a half times the thickness of the steel tested.

4. The strips are all to be cut in a planing machine, and to have the sharp edges taken off.

5. The ductility of every plate, beam, angle, etc., is to be ascertained by the application of one or both of these tests to the shearings, or by bending them cold by the hammer.

6. All steel to be free from lamination and injurious surface defects.

7. One plate, beam, or angle, etc., to be taken for testing from every invoice, provided the number of plates, beams, or angles, etc., does not exceed fifty. If above that number, one for every additional fifty, or portion of fifty. Steel may be received or rejected without a trial of every thickness on the invoice.

8. Pieces of plate, beam, or angle, etc., cut out for testing, are to be of parallel width from end to end, or for at least 8 inches of length.

9. Plates to be ordered by weight per superficial foot, and beams or angles, etc., by weight per foot run. The weight named must always be strictly worked to. In plates over 4 feet wide and ½ inch thick and upward, a latitude of 2½ per cent. above and 2½ per cent. below will be allowed for the springing of the rolls, and 5 per cent. above and 5 per cent. below will be allowed in thinner plates over 4 feet wide. The average weight per foot of the plates ordered is to be ascertained by weighing not less than 10 tons at a time when larger parcels than 10 tons are delivered; if these 10 tons exceed the due weight (calculated as stated above), or are more than the before mentioned percentage below it, the whole may be rejected. In smaller deliveries than 10 tons the average is to be ascertained by weighing the whole parcel. The same conditions as to latitude and mode of ascertaining weight apply also to other descriptions of steel in the contract.

10. In making the tubes and other members of the steel superstructure, all plates or bars which can be bent cold are to be so treated; and if the whole length cannot be bent cold, heating is to be had recourse to over as little length as possible.

11. In cases where plates or bars have to be heated, the greatest care must be taken to prevent any work being done upon the material after it has fallen to the dangerous limit of temperature known as a "blue heat"—say from 600° to 400° Fahrenheit. Should this limit be reached during working, the plates or bars must be reheated.

12. Where plates or bars have been heated throughout for bending, flanging, etc., and the work has been completed at one heat, subsequent annealing will not, as a rule, be necessary.

13. Where simple forge-work has been done, such as the formation of joggles, corners, and easy curves or bends, on portions of plates or bars, and the material has not been much distressed, subsequent annealing will not, as a rule, be necessary.

14. Plates or bars which have had a large amount of work put upon them while hot, and have had to be reheated, must be subsequently annealed. This annealing should be done simultaneously over the whole of each plate or bar when this can be done conveniently. If it is inconvenient to perform the operation of annealing at one time for the whole of a plate or bar, portions may be annealed separately, proper care being taken to prevent an abrupt termination of the line of heat. If the severe working has been limited to a comparatively small part of a plate or bar, annealing may generally be limited to the parts which have been heated, the same care being taken to prevent an abrupt termination of the line of heat.

15. In cases where any bar or plate shows signs of failure or fracture in working the same shall not be used, but the details of the cases must be forwarded to the engineer, in order that instructions may be given as to the disposal of the bar or plate.

16. The curved plates for the tubular compression members will be bent into shape by the steady pressure of specially constructed hydraulic presses, and if any hammering be required to shape the plates at and near the junctions of the struts and ties, wooden beetles and mallets alone are to be used. All straightening and molding of plates and bars, and all flanging, stamping, dishing and forge-work generally, to be done as far as practicable by hydraulic pressure. Strong curvatures and sharp changes of form to be

avoided, and if unavoidable, great care must be taken, and the work must be subsequently annealed if hammers have been used.

17. No punching or shearing or chisel work will be allowed; but all plates must be planed at the edges and butts, all bars machine-shaped or cut with a saw, and all holes drilled. The cutting edges of the tools to be of the most suitable angle and to be kept sharp.

18. For the hot working of plates and bars gas-heated furnaces are to be used, so as to obtain perfect uniformity of temperature, and plant must be provided for the rapid handling of the heated plates and for the protection of them when cooling. Rivets to be of a quality of steel specially approved of by the engineer, and to have large well-formed heads. Wherever practicable hydraulic riveting alone is to be used.

19. The plates and bars in the tubes and other members of the bridge are to be put accurately together, with the butts tightly in contact, and the rivet holes, unless otherwise authorized, are to be drilled through the whole thickness of plates.

20. All plates and bars to be true to form, whether flat or curved, and free from defects of any kind. The workmanship throughout is to be of the highest class, and the utmost neatness of finish will be insisted upon.

21. The whole of the plates and bars must be first cleared of the scale formed in manufacture, by the process in force in the Royal Dockyards, and be then dipped while warm, in boiled linseed oil.

22. Each portion of the work is to be cleaned on completion in the manufacturer's yard, and painted with one coat of Woolston's, Torbay, or other paint, as may be required by the engineer. After erection the whole of the work is to receive three coats of a similar paint, and be left of a color approved by the engineer. The interior of the tubes and other portions of the work may, if hereafter decided, receive a thick coat of tar, pitch, and asphalte, or other composition, in lieu of the final three coats of paint. In every case the painting is to be executed by skilled painters.

23. Manholes must be left for access to the interior of the tubes, and all necessary handrails, ladders, runners, and other conveniences for periodical painting of the viaduct must be provided.

Mr. Benjamin Baker, of Messrs. Fowler & Baker, the engineers of the Forth Bridge, writes me under recent date:

"We have not yet found it necessary to reject a single plate or angle bar delivered at our works by either the Steel Company of Scotland or The Landore Siemens Steel Company, and have had no failure or trouble of any kind. * * * * * *

"We have about 6 000 tons of steel delivered at present. When once you have got accustomed to steel, and the facility of working and welding it, you look upon iron as a poor sort of metal."

The London and Northwestern Railway of England commenced using steel boilers in their engines in 1863; in 1883, they had in use 1 679 engines with steel boilers, giving entire satisfaction.

In the last 20 years (from 1863 to 1883, inclusive) there were made in all the world 35 805 388 tons of Bessemer steel; nearly all this was made into rails.

This, in itself, ought to be convincing proof of the superiority of steel over iron; the practical working of this immense tonnage that has given entire satisfaction. After this experience, where is the engineer that says he prefers iron to steel rails?

If steel will answer better than iron for rails, where it is exposed to

frequent shocks and blows from the modern heavy engine, often at high speed over an inelastic roadbed, why will it not answer better also for structural work where the shock will not generally be as great?

Within the last few years the manufacture of steel castings from mild steel has made great progress, both in improved quality and reduction of cost. These castings are not quite as strong as the same composition would give in wrought steel, provided it is in such shape or size that it can be well worked.

We know, however, the great difficulty of forging properly large or intricate pieces. For this reason such difficult pieces are probably stronger cast than forged.

In making steel castings, the principal difficulties are:

1st. The intense heat required to keep the steel fluid makes it difficult to find a material for the molds that will not be affected by this intense heat, or will not injure the steel.

2d. Great care is required to make the molds so as to allow for the great contraction in cooling (which is double that of cast iron) and yet strong enough to resist the pressure of the fluid metal.

3d. The necessity of preventing unequal cooling, which is liable to cause cracks or fracture.

Many large steel castings have been made in England and France which, from their size and shape, could not have been well forged. These castings have given entire satisfaction. Among them may be named rollers over 8 feet long and 3 feet in diameter; crank shafts and shafts over 16 inches in diameter; rams for torpedo boats, 28 feet from end to end, weighing 6 tons; stern or rudder frames for ships, 27 feet by 14 feet, weight 6 tons.

The Steel Company of Scotland cast of soft steel a gun carriage that weighed in the rough 28 tons, and after being finished, 17 tons, which gave entire satisfaction.

After annealing, castings from mild steel have about the same ductility and about one-half more tensile strength than good wrought iron. All castings from mild steel require to be thoroughly annealed.

Lloyds' Registry of England, which gives the rating to shipping, made a thorough investigation of the advisability of permitting in the construction of vessels, the use of steel castings for stems, stern frames, rudders, tiller quadrants, crank shafts, levers, link blocks, and other parts,

of vessels and engines, that have been made of wrought iron. After careful tests and experiments on a large scale, both in England and France Chief-Engineer Parker reported as follows:

> "Tests were also made, not only upon samples of the material cut out of castings, but also upon castings themselves. And similar tests were conducted upon samples of forged iron and forged steel. The result is that we are now convinced that structures can be made of cast steel, quite as fit for the purpose intended as those usually constructed of wrought iron, and that they can at the same time be made in such a manner as to avoid the uncertainty inevitably associated with large iron forgings, owing to the large number of weldings necessitated in them."

I can see no reason why large cannon cannot be cast in steel as described in a paper read before this Society by Capt. O. E. Michaelis. Of course, one must expect to encounter difficulties and mishaps at the beginning in any important departure from the usual routine, but I am satisfied they would be soon overcome. At any rate, it is worthy of most earnest effort on the part of our Government. Casting these guns with the breach open reduces them to a long and thick cylinder. And I should think they could eventually be cast in steel as easily as the stern frames or torpedo ram mentioned above.

The Rodman plan of cooling slowly from the inside ought to be successful. It is somewhat similar to the views of one of the largest manufacturers of steel castings in England.

In the United States, there have been made good steel castings, such as rollers over 3 feet diameter and 8 feet long, and cylinders 6 feet long and 3 feet diameter, with 10 inches core. Making the steel gun is only multiplying the cylinder 4 to 8 times.

These guns must certainly be much stronger than those of cast or wrought iron, and perhaps even better than those made of wrought steel, owing to the difficulty of working properly such large masses under the hammer. Wrought steel, when it can be properly worked, is stronger and more ductile than cast steel of same composition.

Engineers should not expect too much from wrought steel or steel castings. As steel can be had with tensile strength of 150 000 pounds per square inch, there is great temptation to make use of high tensile strength in order to save weight. But this saving is at the expense of reliability. I would not advise its use in any case, whether in compression or tension, with a greater tensile strength per square inch than 70 000 pounds. This will give a very reliable and uniform material, with

elastic limit of about 40 000 pounds, which can be worked up to very closely, owing to the great uniformity in steel. In my opinion, this will make a stronger and safer structure than if made of stronger steel.

When this limit is much exceeded, both steel castings and wrought steel become unreliable, cracking and breaking without apparent cause. This uncertain action or quality of steel, when of greater tensile strength than 80 000 pounds per square inch, must be governed by some law; but as yet this law has not been discovered. This action is so uncertain that I know no word that expresses it so well as "caprice." This is not very scientific, but it expresses this peculiar uncertain action very correctly. This caprice increases with the tensile strength, commencing, say, at about 80 000 pounds per square inch tensile strength, the percentage of its increase being much greater than that of the tensile strength. Until the laws governing this capricious quality are known, and the remedy found and applied, engineers would do well to confine their work to the preceding limit, leaving the range between 70 000 and 80 000 pounds as an extra factor of safety.

Very great advance has been made in the manufacture of soft or mild steel within the last few years, by which the quality has not only been improved, but the price reduced; for the best steel suitable for boiler purposes to about that of good wrought iron. This gives the engineer at about the same price per pound a much more reliable and stronger material, which, consequently, allows him to reduce the weight and cost.

In a few years, an order for wrought iron for structural purposes will be as much of a curiosity as an order for iron rails would now be from a rich road with heavy traffic.

At a later date steel castings will largely take the place of difficult or heavy workings that are now made in wrought iron, or wrought steel, or cast iron. Cast iron will be confined to cheap works, where strength is not required.

Engineers, especially those engaged in structural branches of the profession, should act upon the conclusion that, in engineering, the iron age is rapidly passing away, as the stone age has done, and will soon be replaced by the steel age.

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ELECTRICAL TRANSMISSION FROM NIAGARA.

By BENJAMIN RHODES, M. Am. Soc. C. E.

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A remark commonly attributed to Sir William Thomson has been frequently and variously quoted, the substance being that the water-power of Niagara could be utilized by transmitting it electrically to great distances.

A recent number of an electrical journal* says that "little or no profit can be derived from the production of electric light (presumably by steam-power), at a price per unit below that of illuminating gas."

Dynamic electricity is used at present substantially only for the electric light, but this use has become a great and growing industry; therefore, if there is any truth in the statement that electric light cannot be profitably produced by steam-power, then Sir William Thomson's transmission scheme becomes of vast importance. It is the object of this

* *The Electrician*, New York, May, 1884.

paper to show what has been done and what may be done toward the utilization of Niagara for electrical purposes.

Power of Niagara.—The power of Niagara can be estimated very approximately. The average flow of the river, according to the many careful measurements of the U. S. Lake Survey, is 275 000 cubic feet per second. The fall in the river through the rapids immediately above

the Falls is	65	feet.
Height of the Falls	165	"
Total	230	"

Then we have for the whole power:

$$\frac{275\,000 \times 230 \times 62}{550} = 7\,000\,000 \text{ h.-p.}$$

(Seven million horse-power.)

To utilize this amount of power by water-wheels, generate electrical currents and transmit to various cities within 500 miles, would necessitate a plant representing at least five thousand million dollars. Such figures as these give some idea of the enormous amount of power here in reserve.

Power already developed.—A small proportion of the power of Niagara is already utilized, and a much larger amount can be developed at moderate cost. On the Canada side the entire use is represented by a small overshot wheel, under 6 feet head, which has for many years propelled a solid piston single acting pump, furnishing a meager supply of water to the adjoining village.

On the American side, along the rapids, on Goat Island, and the mainland, there are five separate raceways, using 4 to 16 feet head, and developing in all 800 to 1 000 horse-power, most of which is now in actual use. If the project for the appropriation of lands for a State reservation at Niagara is carried out, all these races will come within the fixed bounds of the park, and will, of course, be odious in the eyes of the Commissioners, and be swept away.

The greatest power now in use at Niagara, however, fortunately lies outside of the proposed State Park. The Hydraulic Canal is a work of great importance. It was constructed about 1855, and is cut through solid rock across the peninsula on which the village of Niagara Falls is built, taking the water from the exteme head of the rapids and discharging below the Falls, giving opportunity to use the entire head of 230

feet. The lower end of the canal is at such a distance from the Falls that the "busy roar and hum" of the factories will be quite unheard by the romantic visitors, who see only beauty, not utility, in the great cataract. The canal is nearly one mile long, and was planned 100 feet wide and 10 feet deep. It has been excavated but 70 feet, and half the distance only 35 feet wide, and is at present partially filled with debris, being at certain points no more than 5 feet in depth. At the lower end is a basin nearly at right angles to the canal, which may be extended, as needed, along the river frontage belonging to the Hydraulic Power Company. The canal lay idle for a quarter of a century, and it remained for an enterprising citizen of Buffalo, possessed of large capital as well as zeal, to open up the great power to the world. At the time of his purchase, in 1878, there was only one water-wheel on the canal. There is now a large and increasing number of buildings for manufacturing purposes distributed along the high bank of the river, using an aggregate of nearly or quite 5 000 horse-power. The wheels in these buildings are set under heads of from 50 to 100 feet, and discharge the tail water over the side of the precipice, the various streams falling over 100 feet to the river below, making a sight of rare beauty, but suggestive to the engineer of great loss of power. Some of these wheels are of large size when the head is considered, several being capable of giving 1 100 to 1 500 horse-power each. The use of wheels of so great power was a step in advance of anything previously attempted in this line, and, as in all cases where there is lack of experience, difficulties were met. Without going into detail, it will suffice to say that fragments of water-wheels may be found in the vicinity of all the wheel-pits where high heads are used, and that water-wheel manufacturers seem to be learning a lesson long ago taught to bridge builders—to use no cast iron. The last few years have seen great improvements in the making and setting of wheels, and the working of all the mills is now regular and continuous.

Further development of power at Niagara may be largely made at moderate expense. The Hydraulic Canal can be deepened and widened to keep pace with demand for power, and with further experience wheels may be set under greater heads; the total amount thus made available here being equal to the necessities of many years. It may safely be said that the use of Niagara has just begun. Low water is unknown, troubles from ice are slight, hours of use are not limited to 8 or 10, but 24 hours in the day and 365 days in the year unlimited power is ready,

making this the most reliable as it is the grandest water-power in the world.

Application to Electricity.—The application of the water-power of Niagara to electrical purposes has been limited, being hitherto confined to the local use of the electric light; but this use has been such as to give much valuable experience.

A Brush dynamo has been in use in Prospect Park for the illumination of the Falls and grounds since July 4th, 1869. This machine is run under peculiarly favorable conditions, having always the same number of lamps in circuit, power supplied by a water-wheel of proper capacity, and the plant operated only two hours of each day. The working has always been smooth.

A Weston dynamo, with a service lamp and reflector, was for some time used to light the beautiful rapids in the rear of the Cataract House. Some difficulty was found with this plant, not, however, due to the power.

Several isolated Edison installations have been made in various mills, the dynamo in each case being run by the water-wheel which furnishes power for the mill. While the power is continuous, the light is excellent, the only difficulty with such a plant being that in case of shutting down for repairs auxiliary power must be supplied for the dynamo, or other light used.

A local Brush company was organized in the fall of 1881, and has since been lighting the streets and dwellings of the village with 40 to 60 lamps. The company has met with not only the usual difficulties of such organizations, due to inexperience and the sudden introduction into general use of new machinery and unfamiliar principles, but, in addition, other troubles, due to the interruption in the power from various causes, so that a steam plant has been maintained by the side of the water-wheel. As heretofore noted, the improvement in power has been marked, and it is probable that the steam plant will be used hereafter only in such extraordinary emergency as might be classed with the bursting of a steam boiler or the destruction of a building by fire. Experience has shown the immense difference in cost between the use of steam and water-power. Electric street lights are furnished profitably at a price much lower than at any other place, and if the number were greater the price could be still further reduced.

The future application of Niagara's power to electrical purposes is

an interesting subject. The local use will keep pace with the growth of the town, but will, of course, be comparatively small. In order to transmit currents of electricity profitably to a distance, several conditions must be observed:

1st. The cost of transmission must be less than the difference between the cost of steam and water-power.

2d. The distant point must be one where the currents of electricity can be used; and

3d. Where water power cannot be obtained.

There is no point so likely to fulfill these conditions as the city of Buffalo, and the project must be proven practicable here before being attempted to larger and more distant cities. The estimates following are based upon the Brush system, not on account of any merit in this beyond other systems, but because it happens to be here in most general use.

There are in this city 400 arc lights, requiring the use of steam plant of about the same number of horse-power. The number of lights is increasing here, as in other cities, and it may be assumed that there will be 1 000 lights in use within two years. The length of circuit required between Niagara Falls and Buffalo is about 50 miles. There are now in operation in various cities circuits 10 to 12 miles in length, and Sunday nights, when fewer lights are used, circuits are used in some cases to a length of 30 miles. Estimates are therefore based on practice as well as theory. Experience has shown that 40 to 60 lights can be run on one circuit with an electro-motive force of 2 000 to 3 000 volts; but a greater number requires a current of so great intensity as to be in some danger of burning the insulation on the dynamos, as at present constructed. There is no doubt the dynamos will be hereafter improved in this respect, so as to permit 100 arc lights in circuit. Such an improvement will very materially reduce the cost of transmission to great distances. As the resistance of the circuit and consequent loss of power varies directly as the length, and inversely as the area of the wire used, there will be found for every case a size of wire such that the sum of its cost and the capitalized loss of power will be reduced to a minimum. The size of wire will be less for water-power than for steam, and the economical size for a transmitting circuit of (say) 50 miles between Niagara Falls and Buffalo is found to be No. 8, B. W. G., or $\frac{165}{1000}$-inch diameter. The cost of erection, complete, of a number of circuits of this length

would be about \$4 000 per circuit. The resistance would be 76 ohms, equal to 16 lamps, or, assuming the very general practice of coupling in series a 40-light and 16-light Brush dynamo, the loss would be about 28 per cent.

The rental of power at Niagara Falls, in large quantities, may be assumed at \$10 per horse-power per annum, delivered on the shaft. The cost of transmission will be interest, repairs and depreciation, which will all be covered by 10 per cent. on the investment. The cost (\$4 000) must be divided by the net number of lamps or horse-powers (40), making the cost per horse-power 10 per cent. on \$100, or \$10, and the entire cost per horse-power of power delivered in Buffalo, \$10 + \$10 = \$20 per annum.

The items of cost of dynamos, carbons, lamps and care of lamps are common to the use of steam and water, and need not be considered. The most enthusiastic advocate of steam-power will hardly claim that it can be produced for 10 to 12 hours a day at less than \$50 per annum, and as used for electric lights, with small engines, the cost is actually nearer \$75 per annum. The saving, then, may safely be assumed to be forty dollars per annum, or on a plant for 1 000 arc lights, the snug sum of forty thousand dollars yearly.

The incandescent light presents another phase of this matter. It is well understood that the great quantity of current required for these lights, and the consequent percentage of loss by resistance, prevents its economical use at a distance from the dynamo, and explains the marked absence of central stations for such lighting in our cities. The use of the storage battery for this purpose may now be said to have passed the experimental stage, and has come into use to a considerable extent during the last few months. By this system the same dynamo used at night for arc lights is run during the day to charge secondary batteries to be used on incandescent circuits the succeeding night—the distance being overcome by the intensity current, which is automatically regulated when in use so as to be suitable for incandescent lamps. With steam-power, the cost of running by day is the same as at night, and the system becomes expensive. With water-power the reverse is the case. The charge for water-power is the same for 24 hours as for 8 or 10, and the interest on plant is also a fixed charge, so that when the expense can be divided between night and day usage the figure above will be reduced to only \$10 per horse-power per year and the saving be doubled.

The use of electro-motors for the reconversion of electricity into power might be touched on here, but this branch, although well advanced in theory, is not so in practice. Many good minds are occupied in perfecting electro-motors for various purposes, and another year or two may see power supplied to customers from a central station, for running anything from a sewing machine to a street car. In such case, the economy of transmission will be still further apparent.

Enough, however, has been said to show that the power of Niagara can be transmitted to a distance of 25 miles, with a great saving over the power of steam, and that with improvements in storage-batteries and electro-motors, this distance can be increased, with economy, to 100 or 150 miles. With further improvements in dynamos and insulating material to permit the use of currents of higher intensity, such as may be confidently looked for, the economical distance may be still further increased, until some of the present generation may see the prophecy of Sir William Thomson literally fulfilled and the power of Niagara used in all the large cities of this country.

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HARBOR WORKS AT COPENHAGEN, DENMARK.

By H. C. V. MOLLER, Asst. Engineer to the Harbor Department of Copenhagen.

READ JANUARY 7, 1885.

Copenhagen is an important harbor of commerce, as well for the trade of the country as for transatlantic commerce, due partly to importation for the requirements of the country, as coal, iron, timber, sugar, coffee, rice, indian corn, etc., and partly to exportation of the products of the country, such as cattle, grain, butter, pork, alcohol, etc.

The favorable situation of the metropolis, at the main passage between the North and the Baltic seas, also gives it importance as a point of storage for bonded goods and as a harbor of refuge for vessels stopping for repairs or for supplies of coal or provisions.

It has, therefore, been a matter of the greatest importance for the city always to keep its harbor up to the standard of the increasing requirements of commerce, both for navigation and for the required facility for loading and discharging vessels; and the aim of this paper is briefly to describe the harbor and some of its constructions, in accordance with the wish of several members of the American Society of Civil Engineers.

Harbor and Roads.—The accompanying map, Plate XIII, shows the plan of the present harbor and anchorage, and also the improvements proposed and commenced for their extension.

The real harbor of commerce (the navy-yard and anchorage situated to the east of this and occupying a considerable area are not considered here) traverses the city in the form of an arch, beginning at the entrance toward the north, extending in a direction nearly south, and ending in a direction nearly west. Its width varies from about 300 feet to 650 feet, and its whole length is about 13 000 feet. It has places for loading and discharging vessels on the whole western and northern sides, and on about 5 000 feet of its southeastern shore.

The narrowness of the harbor prevents the use of cross-piers, and only in a single place has it been possible to build a parallel pier without interfering with navigation.

The depth of water is 24 *fod* (24.7 feet) in most of the northern part of the harbor, and 20 *fod* (20.6 feet) in the remaining part for a distance of about 10 500 feet, the depth referring to the mean water level. No change of any importance in this level is due to the tide, although the large inflow of freshets to the Baltic Sea and gales in the Baltic Sea, the Kattegat and the North Sea sometimes produce a considerable rise and fall of the water level and a consequent current through the harbor.

From the harbor, canals are led through the town on both sides of the main channel ; as these canals are intended for small coasting vessels, their depth of water is only from 12 to 14½ feet.

Along the western and northern sides of the main harbor there runs a quay, intended both for the general road traffic and for transporting, by railway lines, cattle and merchandise between the vessels and the railroad station or the warehouses on the opposite side of the quay. On the eastern side of the main harbor the warehouses are built closer to the bulkhead line, which is here broken by several slips for private use.

The height of the bulkhead above mean water level is about 6 feet.

To the north of the entrance to the main harbor, there is an excellent anchorage ground, situated between the coast line of the city and the artificially filled islands which are partly occupied by the marine fortifications of the city, and partly by docks for repairing and building steamships and for coal supply. This anchorage is so well sheltered that it may almost be considered an outer harbor. About 1 000 feet of the coast line to the north of the entrance to the main harbor is also

used for loading and discharging vessels. The water depth varies here from 18½ to 22½ feet, and through the whole road there has been excavated a channel with 24 *fod* (24.7 feet) depth of water and about 300 feet width, as shown on the map.

Even outside the above-named anchorage, "The Sound" between Sweden and Denmark (the island of Zealand) is much used as an anchorage road, especially for vessels bound for the Baltic or the North Sea.

Proposed Improvements.—The constant increase of the trade of the harbor has necessitated its extension, and the proposal of the Harbor Department to extend the harbor in a northerly direction to about 7 000 feet from the entrance of the present harbor is already in progress.

The preliminary improvement is to make a capacious basin, about 1 250 feet long and 620 feet wide, with 24 *fod* (24.7 feet) depth of water and about 210 feet entrance opening, and also to excavate to 24 *fod* depth outside the basin, as shown on map, Plate XIII. The excavated material will be used for raising the area marked F on the map 6 to 8 feet above mean water level. In the most northerly of these areas of land, it is proposed to inclose a small basin with but 12½ feet depth of water, (the present depth here) for coasting vessels.

The completion of this improvement will provide a place for loading and discharging vessels for a length of about 3 000 feet of bulkhead with 24 *fod* of water, and for a length of about 1 500 feet of bulkhead with 12½ feet of water, and besides this will give a considerable area of land to be used for roads, warehouses, factories, etc., which may be connected with the railroad depot as soon as it is required.

In future it may be possible to continue this improvement to the present harbor entrance by constructing two or three basins of an equal size and depth, and to obtain a depth of 24 *fod* of water in the whole western part of the anchorage, thus establishing a very favorable place for the loading and discharging of large transatlantic steamers.

Harbor Works.—These consist principally in excavating to the necessary depth of water, the deposit of the excavated material, and the construction of bulkheads to protect the land thus gained.

The excavating has been so far executed by the Harbor Department itself, and not until this year has it been given out to contractors. It has been done by elevator-dredges, three of 30 horse-power, one of 20 horse-power, two of 15 horse-power and two of 6 horse-power, the largest of these being about 114 feet long and 32 feet wide, having

its ladder in the center of the hull and its upper bucket-drum astern; each of the 28 buckets holding about 5.5 cubic feet. Some of the other dredges have the whole ladder astern, thus making it practicable to dig closer to the bulkheads or other obstacles. The scows are partly punts and partly dumping-scows, with a capacity of from 35 to 62 tons (of 2 240 pounds), their small dimensions being on account of the narrow space for their navigation, and in order to float them over the shoals which are to be filled.

The raised material is of various kinds, though it mostly consists of a very sticky blue clay (hard pan), and the cost, on an average for several years, has been 21 cents for one ton (of 2 240 pounds), equivalent to 28 per cent. of $0.75, the estimated wages of one man for 10 hours. (I would state here, that as the expense is mostly in wages, this method of stating it is of use for purposes of comparison.) This figure includes the dredges' working expenses, captain, crew, coal, oil, etc., divers' work and cranes for lifting stones, towing of scows, shoveling of the material into wheelbarrows, keeping accounts, wages for the foremen and the maintenance of machinery and tools.

The filling has so far been mainly carried on by wheeling the material out of the scows in wheelbarrows to a grade of 6 to 8 feet above mean water level, and up to a distance of about 100 feet; the expense thereof has been nearly 4.5 cents per ton, which includes the costs for wheeling, grading, foremen, repairs, etc. This amount increases, of course, with the distance, and is, for instance, about 8.5 cents for a distance of 400 feet.

Lately experiments have been made with iron dumping-cars and 18-inch gauge track instead of wheelbarrows; each dumping-car, holding 12 cubic feet, may be drawn by one man. Thus the expense, especially on longer distances, is materially reduced; for instance, being but 5 cents per ton for a distance of 400 feet.

Bulkheads.—Although a considerable part of the canals is embanked by walls of masonry (granite), resting at one foot below mean water level, on a high pilework, the greater portion of the bulkheads in the harbor and at the anchorage consists of an all-wood construction, of which the following data are presented, referring to the accompanying Plates XIV and XV, which show the construction respectively in 10 feet and 20 feet depth of water; the figures on the drawings are in Danish measure (1 inch Danish = 1.0297 inches English).

The construction is composed of a front wall of piles and planking, and of an anchorage framework behind this wall and connected with it by two rows of iron screw-bolts, one row being about 9 inches above mean water level and the other 3 or 4 feet above the same level.

The front wall consists of a row of piles, 3 feet 5 inches apart from center to center, driven with a batter of one foot in fourteen and to a depth in the hard bottom of from 7 to 8 feet. A timber cap covers this row of piles, being connected with the piles by tenons, mortises and wooden pins; adjoining parts of this cap are connected by scarfs 2 feet long and four ¾-inch screw-bolts over one of the piles.

Behind this row of front piles there is first placed a planking in horizontal courses, collected, before placing, into panels, with a length of nearly 30′ 9″, their lower edge shaped to the bottom in the rear of the piles and their upper edge horizontal; the planks in such a panel are kept together by vertical scantlings, 3 feet 5 inches apart from center to center. Being finished ashore or upon a floating scow, the panel is brought to the rear of the pile row, lowered down to the bottom, forced a few inches into the ground, and then fastened at its upper edge by spikes to the piles, this edge being then about 5 inches above the water level. The joints between the different panels are always behind one of the front piles.

In the rear of this horizontal planking there is then driven down vertical sheeting planks to a depth of nearly 3 feet below the surface of the bottom; these planks are sawn off at the same height as the upper edge of the horizontal planking and fixed to this by spikes.

Above this double planking a longitudinal timber is fastened to all the piles, and above this timber again a double sheet of horizontal planks, with breaking joints, constitutes a tight partition for the earth behind it. In order to protect the main cap and increase the tightness, two longitudinal planks are placed in the rear of the cap and the upper planking, as shown on the drawings.

On the outer side of the front piles two horizontal fenders are fastened by spikes to all the piles.

The anchorage framework behind the front wall extends backward from 13 to 35 feet, depending on the depth of water, and consists of vertical bearing piles driven 5 to 6 feet in hard bottom, and connected at the upper ends with a horizontal cross-cap, fastened to the bearing-piles by tenons and mortises, spikes and dogs, as shown on the drawings.

These frameworks are about 10′ 3″ apart from center to center, measured in the direction of the bulkhead.

Above them are two or three longitudinal timbers passing through the whole length of the bulkhead and connected with the cross-caps by cogging them into each other and by screw-bolts. Through the foremost and strongest of these girders and each of the front piles is led a screw-bolt, the diameter of which varies from 1¼″ to 1½″, according to the depth of water. To prevent this girder from canting by the considerable stresses acting upon it as soon as the soil has been filled in the rear of the front wall, it is secured in its position by blocks fastened to the upper side of each cross-cap by one screw-bolt and two coaks.

The other longitudinal girders are fastened in the same manner, and the foremost of these is used to secure the ties (10′ 3″ apart from center to center), which support the upper part of the front wall against the pressure of the filling, to the anchorage framework, while the rear girder rests against the inclined bracing-piles (driven 7 to 8 feet in the hard bottom with a batter of one foot in two), which are the most important members in the whole construction, in order to secure the position of the front wall.

In building a bulkhead of this construction, it will generally be most favorable to commence by placing the bearing-piles, cross-caps and longitudinal girders, as thereby an excellent platform is constructed for the heavy pile-drivers required to drive the bracing-piles and the front piles; and in filling in the backing soil it is especially necessary to commence with filling round the bracing-piles and not to fill up close to the front piles until this material has settled sufficiently.

The material used in the construction is Pomeranian fir, except in the bearing and bracing-piles, the material of which is Swedish spruce, a lighter and looser kind of wood than the former; sometimes the cap of the front wall and the foremost girder of the anchorage framework are made of oak.

All timber in the rear of the front wall and more than one foot below mean water level is protected against decay by embedding it in blue clay. Protection against the teredo is established by coating the front piles on all four sides and the outer side of the planking with wrought sheet-iron, Birmingham W. G., No. 19 (1.69 pounds per square foot), from one foot below the bottom to one foot above mean water, fastened by 3″ nails. Lately it has been tried to substitute for the sheet-iron on

the outer side of the planking a sheet of tarred felt between two sheets of thinner horizontal planks instead of having only one sheet of thicker planks in the panel; but no data has so far been obtained as to this improvement.

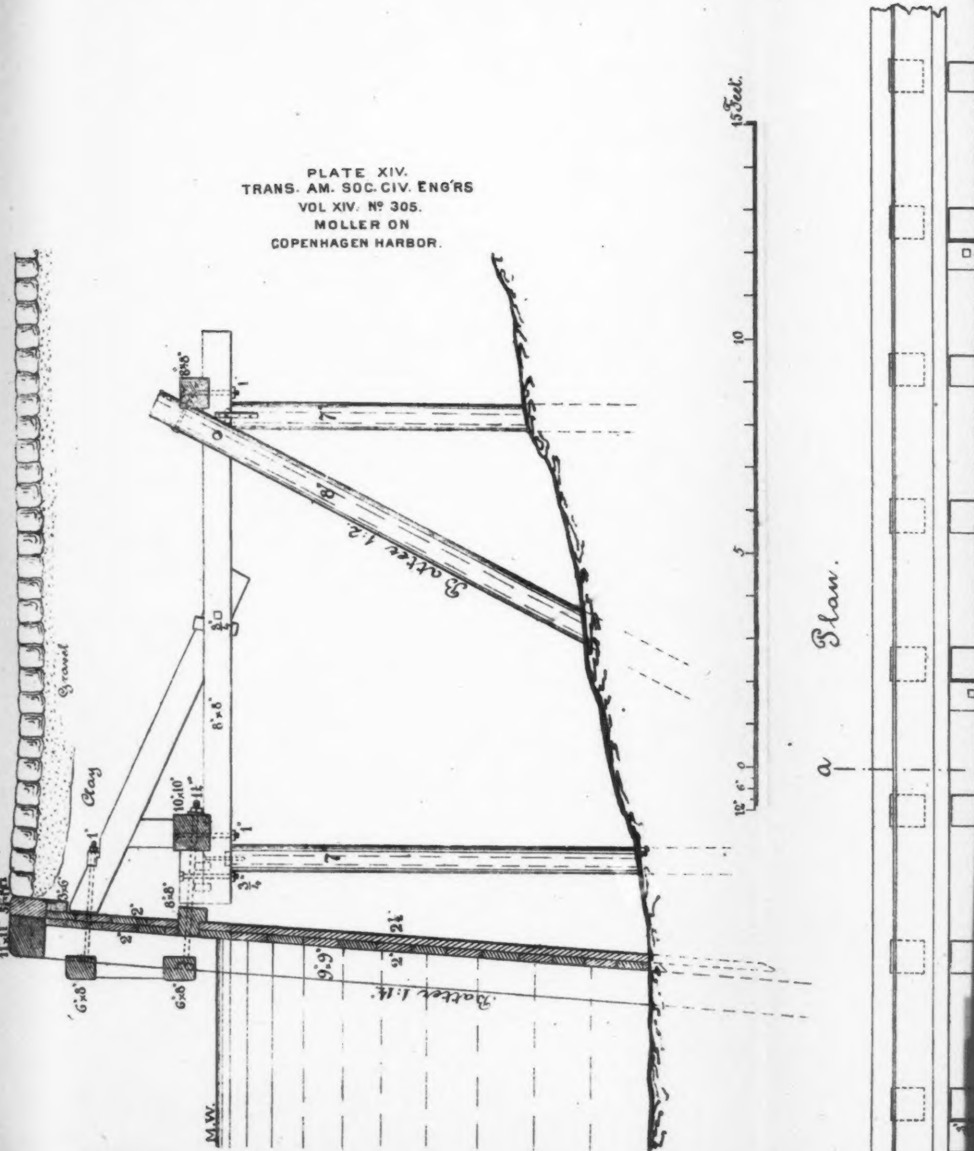
The portion of this structure above mean water level will stand against decay, say 25 years, but can then easily be repaired by sawing off the front piles about 6″ below the water and placing thereon a horizontal cap, secured with tenons and mortises, this cap being a base for a new timber wall anchored to the old anchorage framework and extended up to the grade of the bulkhead.

Sct Jörgens Sö
Peblinge
ens Löb
Kalvebod
Enhornets B
Elefanten
Löwens

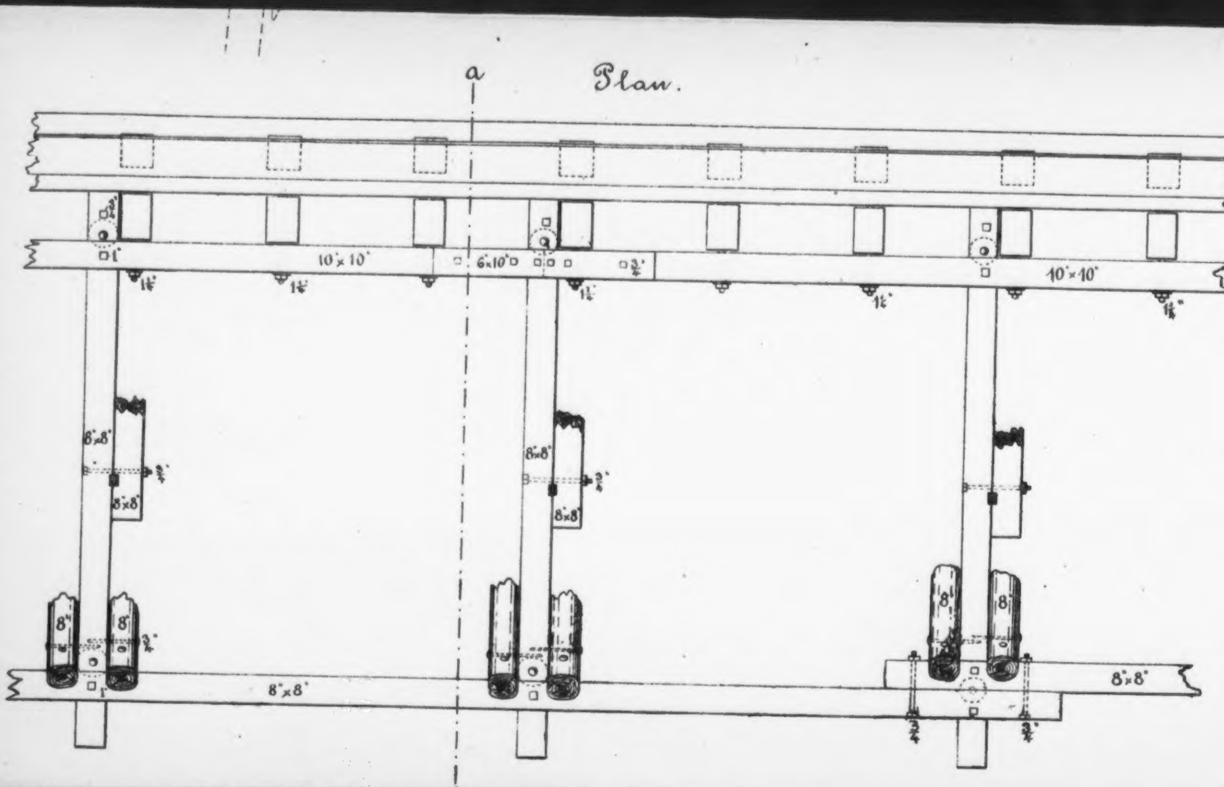
Peblingesö
Sortedam Sö
FÆLLED
CITADEL (FREDERIKSHAWN)
Inderrenden
Toldbod
Arsenal
Söstrene
Maskin og Skibsbyggeri
(Refshale Ö)

PLATE XIII.
TRANS. AM. SOC. CIV. ENG'RS
VOL XIV Nº 305
MOLLER ON
COPENHAGEN HARBOR.

PLATE XIV.
TRANS. AM. SOC. CIV. ENG'RS
VOL XIV. Nº 305.
MOLLER ON
COPENHAGEN HARBOR.



Plan.



2'x10'

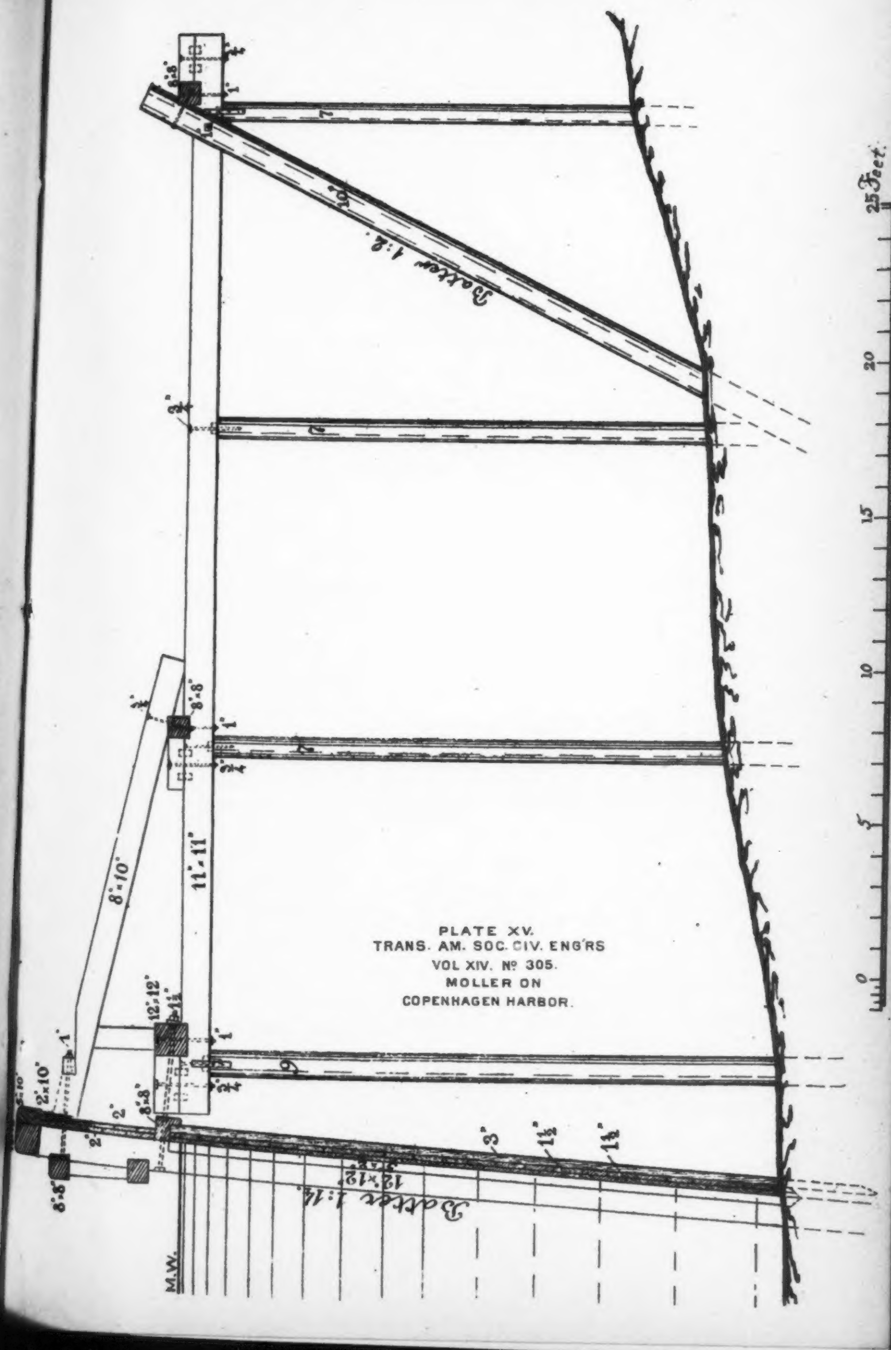


PLATE XV.
TRANS. AM. SOC. CIV. ENG'RS
VOL XIV. Nº 305.
MOLLER ON
COPENHAGEN HARBOR.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

306.
(Vol. XIV.—May, 1885.)

DISCUSSION ON LEVEE THEORY TESTED BY FACTS.*

By J. A. OCKERSON, M. Am. Soc. C. E.

In the paper on "Levee Theory Tested by Facts," published in the October Transactions, 1884, the author has announced himself as belonging to that school of hydraulic engineers which advocates the improvement of the Mississippi River by reducing its flood stages and eliminating the low stages. It is hardly probable that the most enthusiastic student of river improvement would urge an objection to a waterway under such complete subjection.

The author of the above paper has long been a careful observer and diligent student of the phenomena attending the alternating high and low stages of the Mississippi River, and his views as to how the very desirable result of "equalization" could be accomplished would doubtless receive well-merited attention from all hydraulic engineers, and particularly those who are interested in this special problem.

* Levee Theory Tested by Facts, by Robert E. McMath, M. Am. Soc. C. E., No. 291, Vol. XIII, October, 1884, page 331.

I am somewhat familiar with many of the "facts" quoted, and I cannot agree with the author in the statement that "all facts" warrant the conclusions reached by him; neither is the interpretation of the data given entirely satisfactory. As a matter of engineering possibility, I have not the slightest doubt that the floods of the Mississippi River can be controlled and its navigation improved.

But, as I do not profess to have mastered the intricacies of the problem, and do not believe that a satisfactory solution has yet been reached, I shall not be expected to offer a substitute for the plans already proposed. For my own part, I will be satisfied if I can add even a little to the general stock of information by citing some known facts.

The table given on page 333, Vol. XIII, of the Transactions, purports to show that "wide places become subject to deposit at high, and to scour at low stages, a reverse action occurring at the narrow sections." In using this table, however, it should be borne in mind that "change of channel depth" is, in most cases, quite small, and much larger differences might be shown in different determinations of the depth at the same stage. These differences may be due to discrepancies in the soundings themselves, by the soundings not being taken at the same point, or, if so, by a slight lateral shifting of the channel, so that one set of soundings might miss the maximum depth entirely. So it will readily be seen that, while the table may suggest the conclusions, the evidence is far from being positive. Furthermore, in order to enable the reader to give the data its proper weight, he should be informed as to what the channel conditions are, both above and below. The table ends with a section just above where the channel becomes quite narrow and where high and low water widths are essentially the same. Under the latter conditions changes occur which cannot be attributed to changes in "relative width." Numerous causes operate to affect channel conditions, among which may be mentioned a flooded tributary producing back water, an outlet which induces deposit below the opening, the character of bed and banks, and obstructions of various kinds. These do not yield to solution under the doctrine of relative widths; hence it is evident that the latter is only one link in the chain and should not be regarded as universal in its application.

A careful scrutiny of a hydrographic map and a large number of plotted sections between Cairo and Donaldsonville develops the fact that, as a general rule, to which there are but few exceptions, the width

of the sections does not change for stages ranging from bank full to, perhaps, 15 feet below. That is, both banks are vertical for a distance of 5 to 15 feet, or more, from the top. For this range, then, there is no change in relative widths to account for changes in hydraulic capacity.

It is well known that deterioration of channel depth takes place on a rising stage; still there can be but little doubt that high water outlets exert a great influence in the same direction.

The extent of the deposits in the immediate vicinity of crevasses at four different points, as derived by comparing the areas of sections before the flood of 1882 with the areas of same sections as determined after the floods, is shown in the following table :

Number of Sections Compared.	Average Area Before Flood.	Average Area After Flood.	Difference.
29	67 147 sq. ft.	64 947 sq. ft.	22 00 qs. ft.
16	81 494	70 494	11 000
18	62 700	54 300	8 400
7	98 630	74 830	23 800

As a result of the observations at Lake Providence, it is stated that "at the flood stage in April (1880), at which time the river overflowed its banks the entire length of the reach, a marked decrease of area occurred at nearly every section." The observer further states, that on 18 out of 23 sections, "a deepening of the channel takes place as the river passes from a low to a medium stage." (Rep. M. R. C., 1882, p. 92.)

The author of the paper under discussion explains the cause of deposits below a crevasse by assuming that the "velocity is accelerated for miles above the outlet, provokes local scour, and brings down material which passes into the normal current below the outlet, where it is dropped."

It must be admitted that the velocity above the outlet is increased as stated, but if the action of the outlet has such a powerful influence on a particle just above the opening, is it not reasonable to suppose that it will have some influence on a particle below the opening? Supposing

that instead of considering the particle "A," as shown in Fig. 2, Plate XLIV, and reproduced here (See Fig. 1), we take the particle "B" just

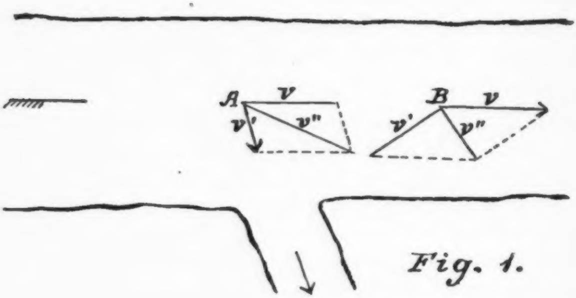


Fig. 1.

below the outlet, and complete the parallelogram, and we find $v'' < v$.

Every one who is familiar with crevasses is aware that immediately below the opening the current is in the opposite direction to that of the main channel. The distance to which this influence extends depends on the size of the crevasse, and the slope of the land over which it flows.

This action was shown in a very decided manner in the case of the "Goodrich Break." Above this break the channel was divided by Island 97, and a bar at the foot of the island extended far below the break. The influence of the crevasse was so great that the water was deflected across the bar, and cut a deep channel through it near the foot of the island (See Fig. 2).

In the Davis crevasse, near New Orleans, the influence of the draft of this break was felt some distance out in the river. In fact, the force of the outflowing water was so strong that the steamer *Patrol* was drawn through the crevasse, as she was not able to stem the current with engines working under full head of steam. Below this break was a strong current running in the opposite direction to the normal flow.

Again, the claim for excessive local scour is confronted by the fact that the maximum bank erosion does not occur at an overflow stage, but at a medium and falling stage.

Bearing these facts in mind, a more satisfactory explanation of the phenomena presents itself in the statement that a crevasse causes an in-

crease in the velocity above the outlet, which induces some increase in erosion of bed and banks, and the deposit below the outlet is due to the additional load derived from such erosion and the slackening of the normal current caused by the deflecting force of the outlet.

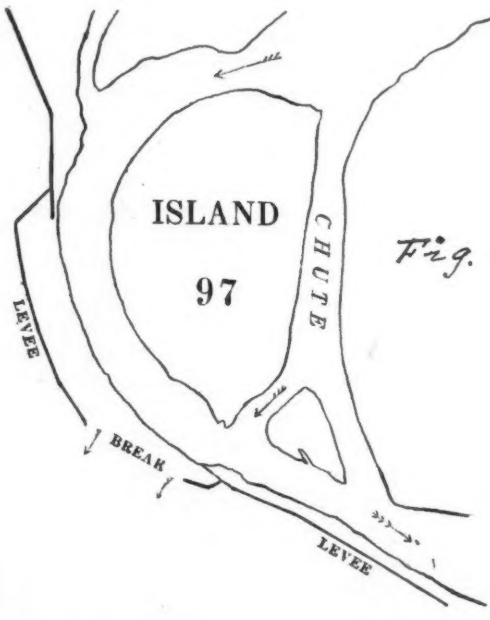


Fig. 2

In regard to the shoaling on the Hay's Landing reach, the author says: "I explain it as the result of back water, and nothing else." This back water was caused by the outflow from the Yazoo Basin, and it must be evident that the best way to remedy the evil in this case then would be to confine the water to the channel along the Yazoo front. Then there would be no back water and, consequently, no shoaling.

As bearing on the question of quantity of material eroded, which, the author says, "must be sought for and shown," it may be stated that from the banks alone the caving from Commerce Cut off to St. Louis Landing (80 miles), from 1880 to 1883, amounted to 2 231 726 cubic yards

for each mile of river. At Darnell's Landing, the bank has caved at the rate of over 600 feet per year during the past five years.

"Depths given by navigators" should never be used, except as showing general conditions. They estimate their position upon the bar and not infrequently fail to find the deepest channel. The large discrepancies in the soundings recorded on different steamers passing the same bar at about the same time show this plainly. Furthermore, they often "run aground" when there is ample water near by to float them. A few inches lighter draft, and they would have made the crossing without hindrance, and reported a depth that was not the "best water" by any means.

On page 349 the statement is made that, "taking the known history of the Mississippi, there has been a slow but decided deterioration of navigable channel."

If we take the testimony of navigators which the author has accepted as sufficient, we find that, in 1836, the average depth of water on the shoalest bars, from the mouth of the Ohio to the mouth of the Arkansas, "was about 4 feet," and from the latter point to the mouth of the Yazoo, "about 5 feet." In 1857, "an increased depth of 4 feet" from the Arkansas to the Red River was reported.

In 1874, we find 15 places less than 7 feet and 9 places less than 6 feet deep between the Ohio River and Lake Providence. (See Rep. M. R. C., 1881, page 128 ; Chief of Eng.'s Rep., 1875, page 519.) In 1883, the same reach showed 7 places less than 7 feet, and no place less than 6 feet deep. The lowest stage in 1874, as well as the highest stage just preceding it, were about a foot lower than the corresponding stages of 1883.

Continuing the comparisons of the last two dates, we find that, of the shoals which have remained in the same locality, 10 show a greater depth for the later date, 2 less depth, and 1 the same depth. On the whole, the evidence does not warrant the conclusion that there is a progressive deterioration of channel.

The peculiar relations existing at the mouth of the Red River and vicinity will, perhaps, justify the introduction of a map, Plate XVI, showing the Mississippi River as it was in 1774 and also in 1883. The former was copied from a map made by Wm. Wilton in 1774, and the other is from recent surveys made by the U. S. Engineers. It will be noticed that in the former the main channel of the river flowed around the bend, which is now called "Old River," and the Red River, as well as the Atchafalaya,

or "Pelousas," as it was then called, connected directly with it. Three cut-offs have occurred in this vicinity, viz.: Homochitto, Shreve's and Raccourci. The two latter were artificial, Shreve's cut-off being made by the U. S. Engineers and Raccourci by the State of Louisiana. The combined effect of these three was to shorten the distance about 40 miles, or about two-thirds of the distance around the old bends.

Under the old conditions, it seems as though every facility was offered for the river to take a short cut to the Gulf through the Atchafalaya, which is 150 miles shorter than the Mississippi. At that time it was also free from "raft," as the early records state that "It was first obstructed by timber in 1778." But, since then, the distance by way of the bayou has been increased some 6½ miles in consequence of Shreve's cut-off, and in October, 1883, the old water way between the bayou and the main river was almost dry, "a width of about 3 feet, with less than 1 foot depth, being all that remained of the river."

At present the tendency seems to be to increase the distance between the river and the bayou by the elongation of the point just above the outlet, and the inclination of the bend to follow the old Raccourci Bend southward, rather than a westerly movement toward the Atchafalaya.

Referring again to the map, and noting the similarity in size of the Red River and the Atchafalaya, as shown at the earlier date, and the continuity in direction, as represented on the later map, and knowing that "the banks of the latter are composed of soil identical with the chocolate, maroon-colored mud of the Red River," the idea is suggested that at some early time, before the bend around Turnbull Island had become so elongated, the Atchafalaya was a part of the Red River, and that the latter flowed directly to the Gulf, and was only diverted to the Mississippi in consequence of the encroachments of the latter, which cut it in two.

If this is true, then the Red River was at one time entirely "divorced" from the Mississippi; at a later period the whole volume passed down the Mississippi in consequence of the filling up of its old bed, now called the Atchafalaya. At the present time the volume is divided between the Mississippi and the Atchafalaya, the current flowing both to and from the former. During the year, the number of days of inflow and outflow are about equal.

Now, as to the havoc which it is supposed would be created by carrying the entire volume down to the Gulf by the main river. Mr

McMath claims that the principal part of the erosion would take place at the banks rather than the bottom in consequence of the layers of clay which "are exposed endwise in the banks."

The clay layers are horizontal, and if the bottom of the river were the same, then the claim might hold good. But a section of the river approximates the form of a triangle with an apex at the bottom and near one bank; hence the clay layers lying between the shoalest and deepest part of the section are also exposed endwise and subject to the action of the water at all stages. An inspection of the sections given in plates VI to IX, Rep. Miss. Riv. Com., 1883, shows that the areas of the sections might be increased at least 30 per cent. by erosion of the bed alone, so that the form of the section would be nearly rectangular. Navigation below the Red River is all that can be desired; hence no improvement is necessary unless it be to aid in the general scheme for improving portions lying higher up.

The effect of doubling the volume can only be conjectured; but, judging from the results in other cases where the volume has been considerably augmented by means of levees, there does not seem to be good grounds for apprehending such widespread destruction as foreshadowed by the author.

I regard the whole question as one of great interest, and a discussion of known facts should be beneficial, as it will aid those not personally familiar with them to judge more intelligently of the merits of the different plans proposed, and may serve to discover a better solution for the problem of river improvement.

I do not believe that all of the facts have been considered by any one, and the multiplicity of theories is sufficient evidence that a correct interpretation is not always given.

My own personal observations, which cover a period of about eight years, lead me to believe that the main effort should be directed toward stopping bank erosion and establishing a fixed channel. When this is done the stream will be deprived of the great bulk of the material which now goes to make up the bars that obstruct navigation and reduce the hydraulic capacity of the channel.

PLATE XVI.
TRANS. AM. SOC. CIV. ENG'RS
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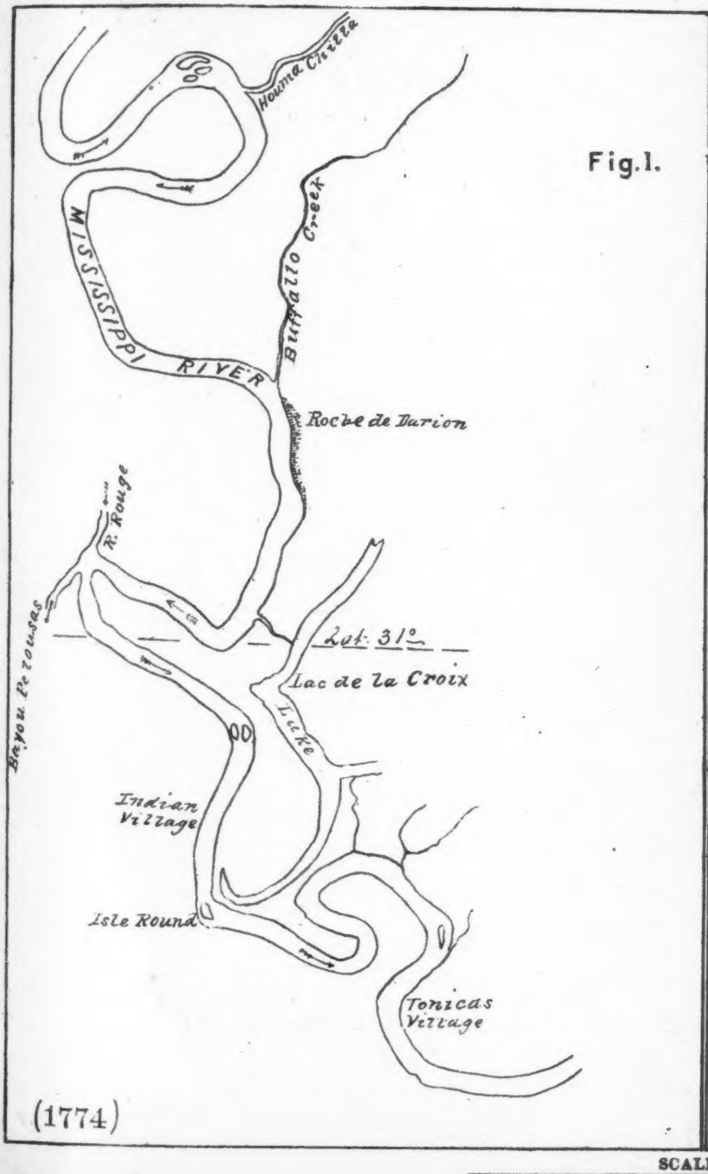


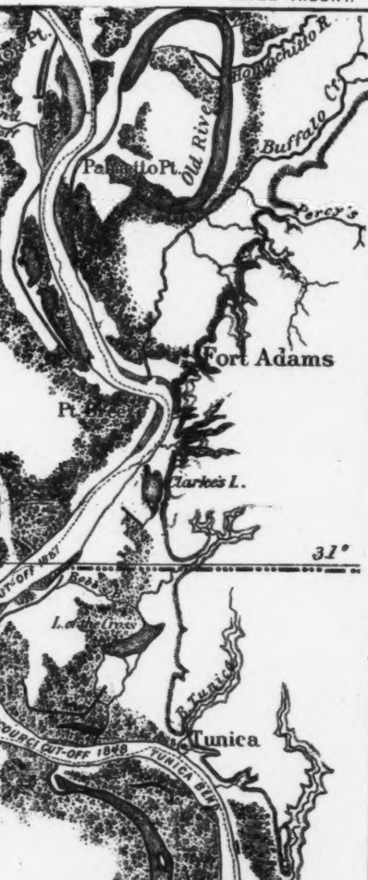
Fig.1.

Fig.2.

SCALE OF MILES
0 5 10


RED RIVER
Union Pt.
Grand Cut-off
Bayou Natchitoches
Lit. Prairie B.
Creek
OLD
31°
B. Coutau
B. Moreau
B. Letsw
Lake Moreau
SHREVES CUT-OFF
RACCOURCI C
Round Lake
Fisher's R.
B. Hazard
ATCHAFALAYA RIV.
Coyle's B.
Robertson's B.
Latenache
Moore's B.
White Vine B.
SCALE OF MILES
10
15

Fig. 2.


Old River
Buffalo Cr.
Fort Adams
Clarke's L.
31°
L. of the Cross
R. Tunica
Tunica
Iowa Pt.
(1883)